M-85

Findings from the M-85 portion of the project are summarized in five parts. The basis for the demonstration and findings is summarized first. Then findings on operations are presented in two sections (data and experience). This is followed by a summary of findings on emissions and fleet economics.

Basis for Demonstration and Findings

The basis for the M-85 demonstration is summarized in five parts: vehicle technologies, fuel properties, fueling facility, building facility, and vehicle activity.

Vehicle Technologies. The 20 Ford M-85 flexible fuel vans were a portion of 200 such vans built by Ford for the California Energy Commission. They had 4.9-liter, in-line, six-cylinder engines (Table 23). As flexible fuel vehicles (FFVs), they could operate on a blend of methanol and gasoline ranging from 85 percent methanol by volume down to zero percent methanol, i.e., gasoline. For CleanFleet, they were operated on a steady supply of M-85 in which the gasoline component was the RFG used in this project.

These vans were built as gasoline vans, then modified in California to become FFVs. Changes to the vehicles included adding a sensor to monitor the alcohol content of the fuel, methanol-compatible materials in all portions of the vehicle exposed to fuel, larger fuel injectors, and a seventh "cold-start" fuel injector.

On average, the M-85 vans weighed about 36 pounds more than the Ford control vans. The catalysts on these vans were a standard model year 1992 catalyst for gasoline exhaust. A catalyst specifically designed to remove formaldehyde in exhaust during cold-start conditions was not used in these vans.

Fuel Properties. M-85 was produced by mixing appropriate quantities of methanol from the California Energy Reserve with RFG from the RFG demonstration site in a tank truck, which was driven to the M-85 site. Average parameters characterizing the M-85 over the course of the demonstration are shown in Table 24.

Fueling Facility. An above-ground, vaulted, 15,000-liter (4,000-gallon) fuel tank and dispenser were installed at the demonstration site (Figure 30). Significant permitting issues were faced to gain local approval to install the fuel tank. In addition to issues involving placement of the tank itself (e.g., appropriate setbacks), the local authorities required upgrading the property near the tank for aesthetic purposes. A concrete masonry wall and new sliding door for vehicle entry were required. This experience points out that, regardless of the fuel itself, necessary construction on a site may trigger a complete review of the property by local authorities.

Table 23. Characteristics of the M-85 and Control Vans

Vehicle Component	Ford	
	M-85	Control
Chassis Model	E250	E250
Engine		
Displacement (L)	4.9	4.9
Type	I6	I6
Compression Ratio	8.8	8.8
Fuel Delivery[(a)]	SMPI	MPI
Fuel Capacity (L)	132	132
Fuel Capacity (GEQ)[(b)]	20.1	34.9
Vehicle Weight (kg)	2,506	2,490
Engine Classification[(c)]	MD	MD
Catalyst[(d)]	G	G

(a) TB = Fuel provided through the throttle body, TBI = TB injection, MPI = Multiport electronic fuel injection, SMPI = Sequential MPI.
(b) GEQ = Gasoline equivalent gallons on an energy equivalent basis.
(c) MD = Vans in California medium-duty class. HD = Engines in heavy-duty class.
(d) Three-way catalyst optimized for exhaust from gasoline (G).

Table 24. Average Characteristics of M-85

Parameter	Units	Mean	Relative Standard Deviation (%)
Density	kg/L	0.787	0.27
Methanol	Vol %	85.4	1.27
Hydrogen[(a)]	wt %	12.7	0.40
Heating Value, net	MJ/kg	23.5	2.29
Reid Vapor Pressure	kPa	50.3	2.52
Particulate Loading	mg/L	0.373	NR

(a) Calculated from hydrogen content of pure methanol and the measured hydrogen content of RFG.

Figure 30. An above-ground tank was used to store M-85 at the demonstration site.

Building Site. No modifications were required for the building into which the vans were driven each day. The building was in compliance with requirements for gasoline-powered vans, which was adequate for M-85 vans.

Vehicle Activity. Over the course of the demonstration, the M-85 vans, on average, logged 25,000 miles compared to the control vans with 25,000 miles (see Table 25).

Table 25. Summary of Vehicle Activity for the M-85 Fleet

Type of Fuel	Average Number of Service Days	Average Total Miles Per Van	Average Miles Per Day
M-85	521	24,969	48
Control	595	25,221	42

Figure 31 demonstrates how the vehicle rotation plan achieved its goal of equalizing the distribution of duty cycles among fleets. Overall the distribution of average miles per day for the M-85 and control vans overlap.

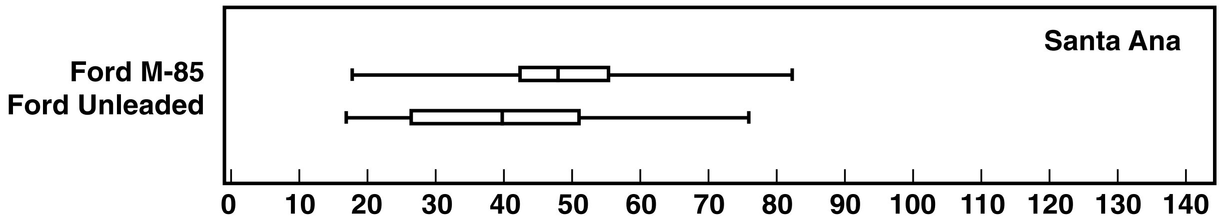

Figure 31. The distribution of the average miles that the M-85 and control vehicles traveled each day overlaps, providing comparable routes.

Operations Data

Operations data for the M-85 portion of the demonstration are summarized for vehicle fuel economy, motor oil, and vehicle maintenance.

Fuel Economy. The mean efficiencies of the M-85 vans (see Figure 32) compared to their controls were -1.1 and -1.7 percent from operational and chassis dynamometer data, respectively. These mean differences are not statistically significant (95 percent confidence); and, therefore, no difference in efficiency is attributed to the M-85 and control fleets.

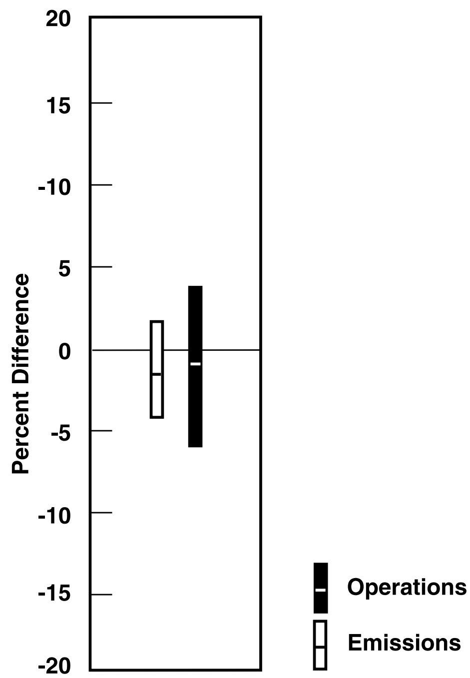

Figure 32. Relative fuel economy (efficiency) for M-85 vans was compared to the control vehicles.

The quantity of fuel stored on the vans, the energy content of the fuel, and the efficiency of the vehicle in using the fuel combine to yield an estimate of the driving range of the CleanFleet vans. Results are shown in Figure 33.

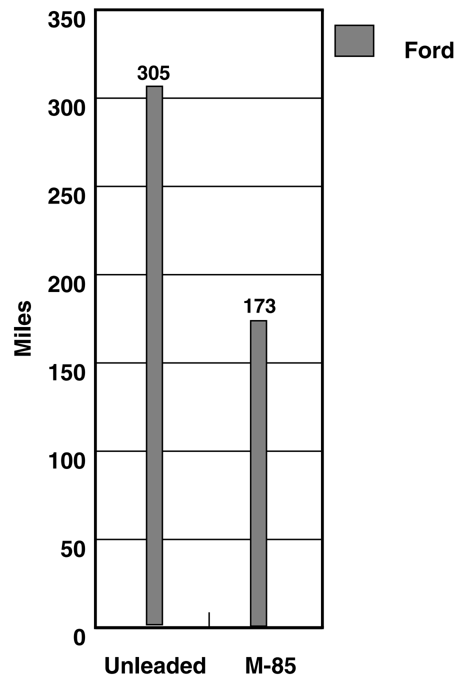

Figure 33. The driving range of M-85 and control vans (on a typical FedEx duty cycle at 40 miles per day) was estimated.

The specific driving range was computed as the ratio of driving range to either the volume of fuel storage capacity or the weight of the fuel system on the vehicles. Results are shown in Table 26.

Table 26. Specific Driving Range of M-85 and Control Vans

Miles Per Gallon Capacity		Miles Per Pound	
M-85	Control	M-85	Control
8.0	8.8	3.8	4.2

Motor Oil. Figure 34 provides information on the properties of used motor oil from the M-85 vans. Average TBN levels in the oil from the M-85 vans were more than twice the levels from the control vans; nitration levels were less. Viscosity was higher; however, the oil used in the M-85 vans was not the same as the oil used in the control vans. For example, it should be noted that the Lubrizol MFV 10W30 oil used in the M-85 vans had an initial TBN of 8.53, versus a value of 6.51 for the Chevron Delo 400 15W40 oil used in all other vans.

Table 27 contains information on the accumulation of metals in motor oil after 10,000 and 20,000 total miles. Metal removal rates for five of the nine elements were essentially the same for the M-85 and control engines. Iron and nickel rates were higher than the controls. A detailed analysis of engine wear, with before and after measurement of key parts, was beyond the scope of this project. A small sample of the various alternative fuel and control engines were, however, torn down for

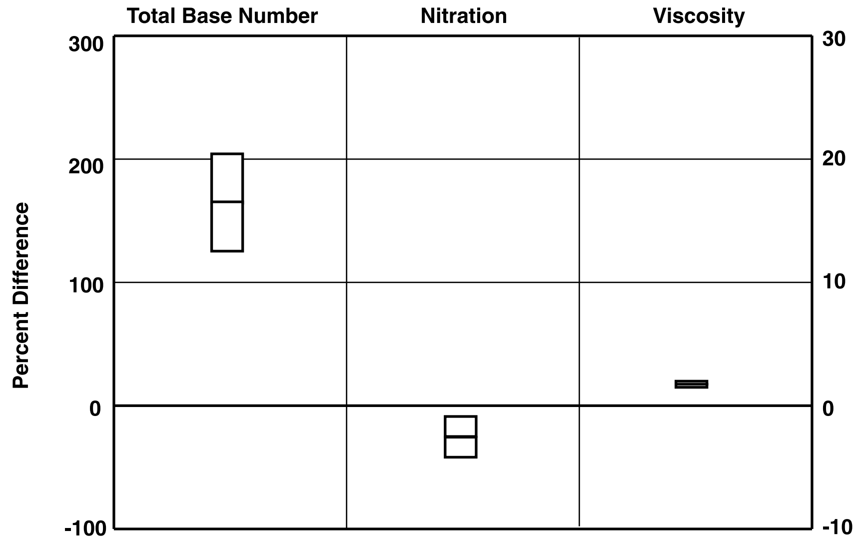

Figure 34. Relative differences in total base number, nitration, and viscosity of used motor oil after 3,000 miles were normalized for M-85 and control vans.

Table 27. Average Percent Difference in Accumulation of Engine Metals in Motor Oil for the M-85 and Control Vans at 10,000 and 20,000 Miles

Metal	Mileage (Thousands)	Average Percent Difference
Iron	10 20	+390 +530
Chromium	10 20	–[a] --
Nickel	10 20	+100 +240
Aluminum	10 20	-40 +51
Lead	10 20	-- --
Copper	10 20	-- --
Tin	10 20	-- +53
Molybdenum	10 20	-- --
Antimony	10 20	-- --

[a] Indicates that the difference was not statistically significant at the 0.6 percent level. This is an overall error rate for all nine comparisons of five percent.

inspection at the end of the demonstration to determine if there were any significant differences in wear or other degradation patterns that might have implications for long-term durability. In the case of the M-85 engines, candidate source(s) were sought for the high level of iron in the oil samples. The only iron/steel parts showing any significant distress that might account for the level of iron/steel found in the oil were the valve train rocker arms and rocker arm pivots. Cursory measurements of weight loss by these parts (12 each per engine) indicate that they might well account for the increase in the cumulative amount of 7.6 grams of iron found in the oil of the M-85 engines over that of the control engines. It is important to remember that the M-85 engines were not full production engines for methanol vans; they were demonstration vans. It could be expected that Ford (or another OEM with its demonstration vehicles) would uncover an issue with metal removal and correct it before mass production took place. In any event, during the demonstration, the engines operated satisfactorily and met FedEx's fleet needs.

Vehicle Maintenance. The M-85 vans experienced a few hardware problems characteristic of nonproduction vehicles. Fuel control modules, the cold start injectors, and some fuel pumps were replaced in the vans. The number of ROs per 100 service days are plotted in Figure 35 for the whole vehicle (dark shading) and fuel-related systems (light shading). The percent difference in ROs per 100 days for the fuel-related systems on the M-85 vans compared to their controls was 46 percent, which is statistically significant.

Availability of the M-85 vans averaged 97 percent (Figure 36). Availability of the control vans averaged 99 percent.

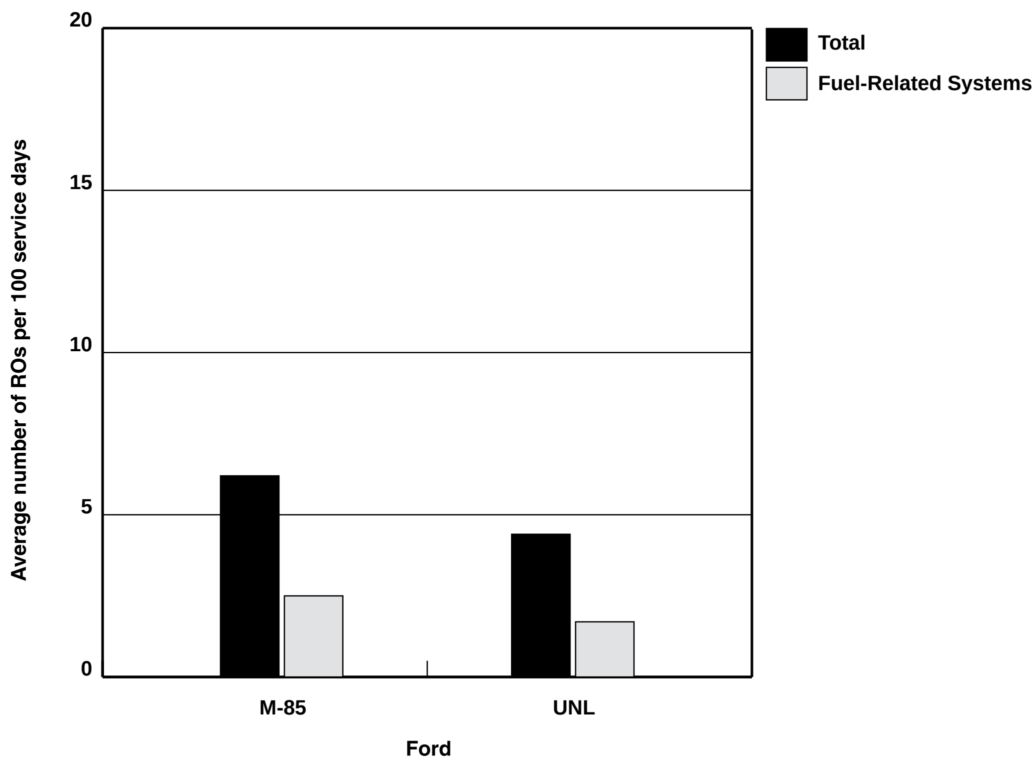

Figure 35. The number of repair orders per 100 days of service for the total van and fuel-related systems is compared for M-85 and control vans.

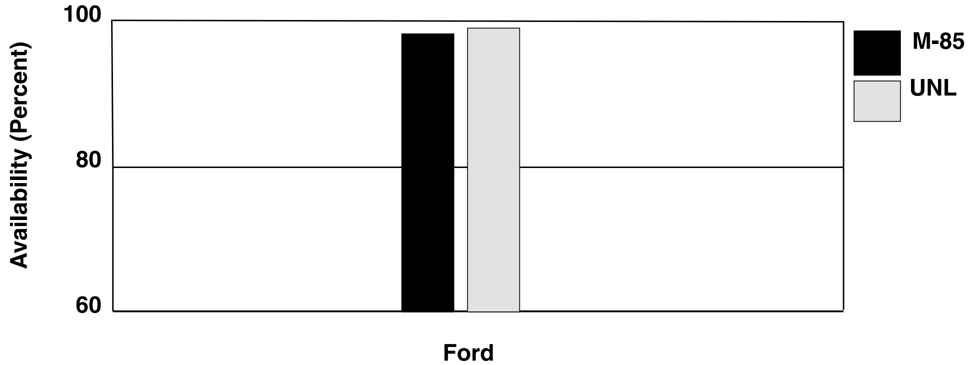

Figure 36. The availability of M-85 and control vans is shown.

Operations Experience

Safety. FedEx experience related to safety in M-85 operations is summarized in two parts: (1) potential exposure of employees to M-85 vapor during fueling and to formaldehyde from vehicle exhaust and (2) incidents such as fuel leaks and vehicle accidents.

Limited measurements were made of methanol vapor concentrations during refueling and near the tailpipes of M-85 vans indoors. Methanol concentrations, when averaged over either the 15-minute or the 8-hour time periods for the limits of the ACGIH and OSHA, were well below the applicable limits.

Formaldehyde is formed in M-85 exhaust, and exposure limits have been established by the ACGIH and OSHA. The CleanFleet M-85 vans were not equipped with catalysts designed to remove formaldehyde during cold start. Concentrations of formaldehyde in excess of the ACGIH guideline were found during morning startup.

During the course of the demonstration, fires occurred in the engine compartments of two M-85 vans. The fires started near the cold-start injector. The cold-start injectors, which were not needed in California, were removed from the vans, and no further problems occurred.

Employee Attitudes. FedEx employees who participated in the demonstration of M-85 vehicles had a positive attitude about using a “clean-burning” fuel to reduce vehicle emissions and improve air quality. They were proud to be driving M-85 vans and reported positive response from FedEx customers who noticed the CleanFleet markings on the vans.

Some 31 percent of the study group reported experiencing health-related problems, citing exposure to fuel vapors and vehicle exhaust resulting in headaches and eye irritation (formaldehyde, a product of combustion, is an eye irritant).

Seventy-five percent of the study group reported no safety-related problems during the demonstration. In spite of two fires in the engine compartments of the M-85 vans, the drivers understood that the problem was solved. The 25 percent who believed they had experienced a safety problem included 19 percent who related to the fires and 6 percent who were concerned about fueling. As the people reflected upon their concerns at the beginning of the demonstration, 44 percent reported a positive change in their attitude about safety and 38 percent reported no change in their attitude.

Concerning vehicle performance, 76 percent of the study group believed that the M-85 vans were about the same as the control vans, and 20 percent believed that the M-85 vans were better than the controls overall.

When questioned about daily operations, some employees noted that the final fuel filter on the M-85 dispenser had to replaced several times during the 24 months as the filters became plugged. Nevertheless, 94 percent of the study group reported that they were able to maintain their regular schedule without interruption.

Nineteen percent of the study group at the M-85 site did not believe that FedEx should convert the entire fleet operation at the site to M-85. Thirty-eight percent favored conversion to M-85; the same percentage had no opinion.

Emissions

As the M-85 vans were used in daily FedEx operations, significant reductions were achieved in the mass of pollutants emitted into the atmosphere for selected compounds. Results are shown in Figure 37 for selected pollutants over the odometer range 5,000 to 25,000 miles. For example, a reduction in emission of CO from the M-85 vans compared to the control vans averaged 26 kg per van. As seen by the confidence interval about the CO mean (the entire interval is below the zero line), there is 95 percent confidence that the mean emission of CO from the M-85 vans was less than from the control vans. The estimate of the reduction in ozone formed in the atmosphere by emissions of NMOG and NO_x is 13 kg. An increase in emission of the four air toxics averaged 0.10 kg (due to the increase in formaldehyde). Carbon dioxide was reduced by 760 kg, while methane emissions fell by 1.3 kg.

Fleet Economics

The estimated cost to a fleet operator to use M-85 in 50 vans in the 1996 time frame is shown in Figure 38. Results are shown before corporate income tax and without tax and other incentives. Three cases are shown for the estimated price of methanol to a fleet in 1996 (f.o.b. California port). During 1994, the price of methanol rose dramatically from historic levels, while in 1995 it began to fall. The price range of 40 to 80 cents per gallon is expected to bracket the price to a fleet in 1996. The total annual cost for the three cases is estimated to be 38.3, 41.5, and 44.7 cents per mile. It was assumed that a fuel storage tank for M-85 would be installed at the site below ground.

Table 28 summarizes the results before and after income taxes, with the effect of incentives included in the after-tax estimates.

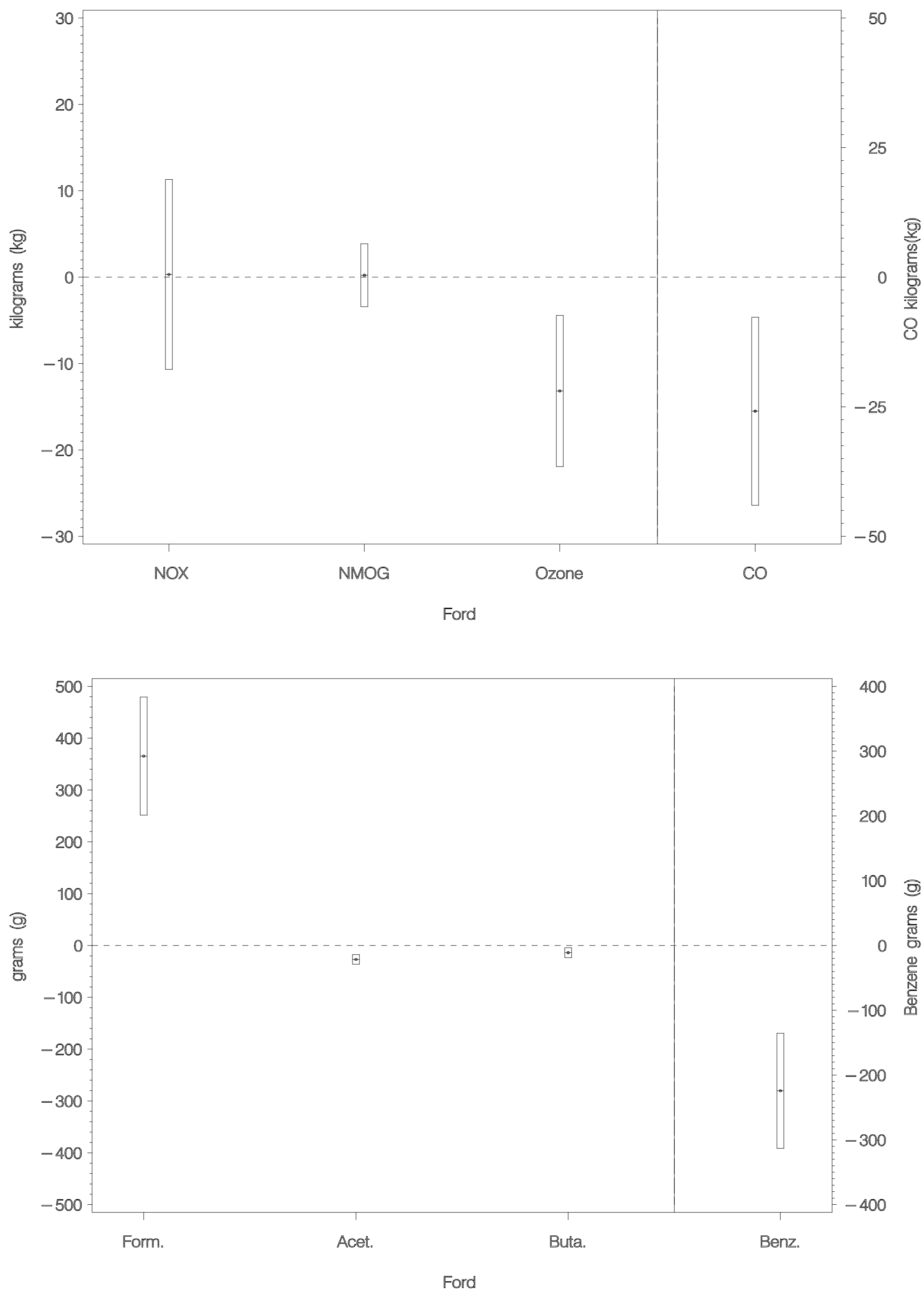

Figure 37. Estimated differences in selected emissions from M-85 vehicles compared with control vehicles are shown over the range 5,000 to 25,000 miles.

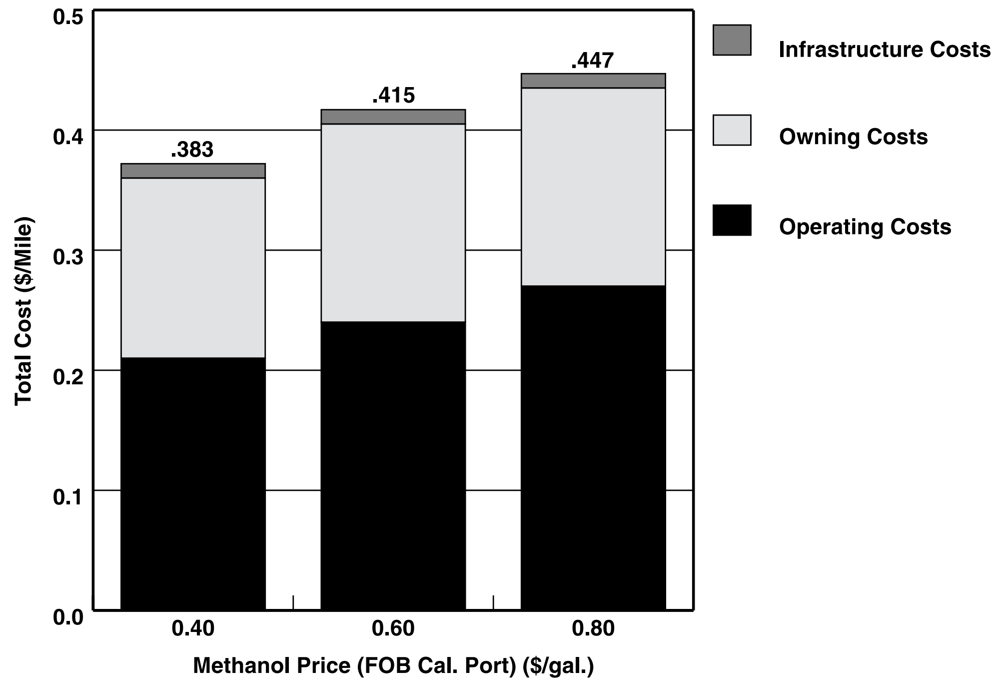

Figure 38. Costs were estimated for an M-85 fleet in a 1996 economic case study.

Table 28. Estimated Total Costs for an M-85 Fleet Before and After Income Tax

Methanol Cost (cents/gallon)	Before Income Tax Without Incentives (cents/mi)	After Income Tax With Incentives (cents/mi)
40	38.3	23.6
60	41.5	25.5
80	44.7	27.3